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US Bank Capital Regulation: History and Changes Since the Financial Crisis

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Legislators and supervisors (policymakers) impose minimum capital requirements on banks because they believe that, left to themselves, banks tend to hold too little.[1,2] Banks tend to hold too little capital because while higher capital reduces the risk of failure, it tends to be more costly than debt. And while bankers worry about failure, they worry less than policymakers argue that they should, for two reasons. First, a bank's creditors (and especially insured depositors) do not penalize the bank for taking on risk, so banks, which can profit from high-earning, risky assets, will tend to make excessively

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[1] Throughout this article, unless specifically noted, the term "bank" will be used as shorthand to mean any insured depository institution (commercial banks, savings banks, and savings and loan companies) as well as any company owning an insured depository institution (bank holding company or savings and loan holding company). The article does not address credit union capital requirements.

[2] In June 2007, then-chair of the FDIC Sheila Bair explained the tendency of banks to hold too little capital: "There are strong reasons for believing that banks left to their own devices would maintain **less** capital – **not** more – than would be prudent. The fact is, banks do benefit from implicit and explicit government safety nets. Investing in a bank is perceived as a safe bet. Without proper capital regulation, banks can operate in the marketplace with little or no capital. And governments and deposit insurers end up holding the bag, bearing much of the risk and cost of failure. History shows this problem is very real ... as we saw with the U.S. banking and S&L crisis in the late 1980s and 1990s. The final bill for inadequate capital regulation can be very heavy. In short, regulators can't leave capital decisions totally to the banks. We wouldn't be doing our jobs or serving the public interest if we did" (Bair 2007).

risky investments. Second, a large bank's failure is thought to have the potential to impose widespread economic impacts, which the banks themselves do not take into account when making decisions. But policymakers do care about these impacts; for one, they are likely to face hostile political repercussions. As a result, policymakers are keen to ensure that banks maintain at least certain minimum levels of capital in order to reduce the danger of failure.

Higher capital reduces the risk of failure because it acts as a cushion to absorb losses suffered by banks (and other types of firms). Capital is the difference between the value of a bank's assets and its liabilities. If the organization encounters financial troubles that reduce the value of its assets, for example, some of its loan customers default on their loans, the bank can still repay its liabilities (meaning avoid insolvency and continue operating) as long as the decline in asset values is smaller than the amount of capital.[3] Therefore, other things equal, the higher the ratio of equity-to-assets, the less risky the bank. Beyond this loss-cushioning role, capital is also an alternative to deposits and debt, providing another means of financing asset holdings.

A reason that capital is more expensive for banks than debt is that interest payments on debt are tax deductible for banks (paid from before-tax earnings), while dividends are paid from after-tax earnings and are not tax deductible. Because debt is less expensive than capital, banks will tend to prefer debt finance to equity (capital) finance. Other corporations, not just banks, have this same preference, because the tax advantage of debt applies to nonbank corporations. But debt's advantage is offset to a degree by the fact that increases in leverage (i.e., the debt-to-equity ratio) make a corporation more fragile. Consequently, as a corporation increases its leverage, its creditors will worry that their investments in the corporation will not be repaid and therefore will increase the interest rate they charge, driving *nonbank* corporations to limit leverage.

In the case of *banks*, however, some of their creditors, such as depositors insured by the Federal Deposit Insurance Corporation (FDIC), care little about the increased fragility high leverage can bring; depositors with balances of less than $250,000 are protected from any loss in value of their deposits in the case of bank failure by an agency of the federal government, the FDIC. Further, in past crises, some uninsured bank creditors have been protected. Because of these forms of protec-

[3] This point is somewhat abridged. Firms with **positive** capital might, nevertheless, become unable to repay their liabilities because of liquidity weaknesses (for example, when short-term liability holders demand repayment and the firm is unable to sell—liquidate—enough assets, or sell them quickly enough, to meet these demands).

tion, bank creditors do not penalize banks for increases in leverage to the same extent that nonbank creditors do. At the same time, bank owners (shareholders) can benefit significantly from risky investments, given that, at least in good times, such investments produce higher profits than less-risky investments. And in bad times, the downside is limited because owners' maximum loss is limited to their investment in the bank's equity, while the government and creditors bear the remainder of the bank's losses (Grochulski and Slivinski 2009, p. 2). Because of the concern that taxpayers will get stuck with bank losses (as occurred during the savings and loan crisis of the late 1980s and early 1990s), policymakers are keen to limit bank risk-taking and require banks to meet minimum capital requirements.

Additionally, some policymakers argue that bank failures (and especially large bank failures) are likely to trigger economy-wide (systemic) calamities.[4] Further, banks are unlikely to account for this risk when deciding how much capital to hold given that most of the costs of systemic problems are borne by others—i.e., are external to the bank. Therefore, banks hold less capital than is ideal from a societal point of view, providing one more justification for minimum capital requirements.

But policymakers see a trade-off between the dangers of low levels of capital (high leverage) on one hand and certain economic benefits of leverage on the other. As discussed by Van den Heuvel (2008, p. 298-99), there may be significant benefits from allowing banks to fund themselves with a significant amount of debt and especially with deposits. Individuals and businesses derive significant benefits from holding checkable deposits in banks. Such deposits provide an immediately available means of payment, such that depositors can meet unexpected, sudden demands for payment, such as an emergency medical or auto repair bill. Further, deposits have a highly predictable value equal to exactly what the investor initially deposited, plus interest. A deposit's value can never decline below this amount, at least as long as the bank does not become insolvent (fail).

Nonbank investments, such as stock or bond investments, generally do not offer this immediate payment and predictable value combination of features. Instead, nondeposit investments must first be sold (and such sales can impose transactions costs), often for a price that is difficult to know with certainty in advance, and then deposited in a bank account, which can then be used for payments. Therefore, the al-

[4] For a discussion of the view that banks are more likely to produce systemic consequences than nonbank firms, see Bullard (2008), section entitled "Why the Financial System is Special."

ternatives lack predictability and immediacy. These features of deposits make them attractive to investors (depositors) and, as a result, banks can pay a lower rate of interest for deposit funding than the nondeposit funding offered by nonbanks. At the same time, while holding a small fraction of deposits as reserves (to meet the normally steady flow of depositor withdrawals), banks can lend out the remainder of their deposit funding to long-term borrowers (such as businesses needing long-term funding and homebuyers), earning a spread for the bank while providing benefits to depositors and long-term loan customers. This blend of gathering short-term deposit funding while making long-term investments is referred to as the process of *maturity transformation*.

While policymakers could reduce the danger of bank failure to almost zero by requiring banks to completely, or nearly completely, fund themselves with equity, doing so would destroy the benefits of maturity transformation. So policymakers must balance the failure-reduction benefits of higher capital requirements with the cost of reducing valuable maturity transformation and the availability of bank-provided deposit services. As a result, capital requirements are set, now and in the past, at something well below 100 percent.

US bank capital requirements were revised along a number of important dimensions following the 2007-08 financial crisis. The goal was to shore up the banking system and reduce the likelihood of another crisis. The changes include new measures of capital and increased minimum requirements.

Government-imposed capital requirements extend to at least the mid-1800s, and requirements that banks maintain minimum capital-to-deposits ratios are found in early twentieth century legislation. Capital-to-asset ratio minimums, not dissimilar from those in place today, were present in pre-WWII regulations. Further, during the 1940s and 1950s, supervisors experimented with some of the fundamental capital requirement features that returned in the late 1980s and early 1990s: capital-to-risk-weighted-asset ratios and capital requirements covering off-balance-sheet activities. Therefore, many of the features that we view as fundamental to our modern capital requirement regimes were first employed decades ago.

Bank capital requirements were strengthened significantly starting with international agreements in the late 1980s (Basel Accords) and later were made more sophisticated and stronger, both before and after the 2007–08 financial crisis with updated versions (Basel II and Basel III—see the **Glossary** for a listing of frequently occurring banking capital expressions and abbreviations) of the initial Basel Accord (also known as Basel I). Postcrisis reforms included not only broad increases in capital requirements and new measures of capital, but additional, more detailed requirements for the largest and most systemically important institutions, including added surcharges and the use of stress testing to evaluate large banking organization capital adequacy. Since the financial crisis, banking companies have increased their capital holdings appreciably.

This article will discuss the history of requirements and the changes made in response to the financial crisis.

1. PRECRISIS HISTORY OF CAPITAL REQUIREMENTS

Bank capital requirements have a long history in the US, going back to the earliest days of federal bank regulation. Early requirements, from the nineteenth century, were quite crude by today's standards. Yet by the early and mid-twentieth century many of the main features of today's capital requirements had shown up, though in some cases only temporarily, such as minimum capital requirements based on a proportion of deposits or assets (1939), risk-weighted capital requirements (mid-1940s), and the inclusion of off-balance-sheet activities in capital measures (1956).

An early capital requirement can be found in the National Bank Act of 1864. The focus of the 1864 capital provision of the act (Section 7) was on the amount of capital needed to form a national bank (a bank with a charter from the federal government). Given that at formation a bank has few if any assets, this capital requirement was a set dollar amount of capital in relation to the size of the city in which the bank was formed rather than the capital-to-assets ratios that are more familiar today. Specifically, Section 7 required that the founders of the national bank had, at origin or within five months of the bank's opening, $50,000 if the bank was headquartered in a city of fewer than 6,000 people, $100,000 for cities of fewer than 50,000 people, and $200,000 if the city's population was more than 50,000.[5] This formation capital requirement had an ongoing component in that national banks were also required to build and then hold an additional capital amount (a "surplus" account) equal to 20 percent of their initial capital requirement, which was allowed to decline when the bank suffered losses, but no dividends could be paid by the bank until the surplus was rebuilt (similar to buffer requirements established after the 2007–08 financial crisis). If the national bank suffered a loss greater than its retained

[5] Dollar amounts from National Bank Act of 1864, Section 7. Five-month requirement from White (1983), p. 16.

earnings and the surplus account, the bank was closed by supervisors (White 1983, p. 16-17).

An early example of a capital rule that was a function of the size of the bank (like today's capital requirements), and therefore increased in some, perhaps rough, proportion to the losses a bank might ultimately suffer, was a 1909 California banking law applying to banks chartered by that state. The California Bank Act of 1909 required state banks to maintain capital amounting to at least 10 percent of their deposits (California Superintendent of Banks 1909, p. 7-8, Section 19). In the 1920s and 1930s, thirteen other states, including large states such as New York, Michigan, and Texas, passed similar statutes for the banks they chartered, typically requiring the maintenance of a capital-to-deposits ratio of 10 percent (Robinson 1941, p. 47-49).

Mitchell (1984, p. 19) notes that in 1914 the Office of the Comptroller of the Currency, the supervisor of national banks (meaning banks chartered by the federal government rather than by a state government), required such banks to maintain a minimum equity-deposits ratio of 10 percent. Following its 1933 creation, the FDIC required banks that it supervised—state-chartered banks that were not members of the Federal Reserve System—to meet a minimum 10 percent equity-to-deposits ratio (Robinson 1941, p. 45). By 1939, however, the FDIC had shifted to requiring state nonmember banks to hold capital equal to at least 10 percent of *assets* (Robinson 1941, p. 46). Mitchell (1984, p. 19) conjectures that the reason for the shift from an equity-to-deposits ratio to an equity-to-assets ratio was that the advent of federal deposit insurance meant there was little need for capital to protect against deposit withdrawals; instead, capital was now intended to act as a cushion for asset losses. Over the period in which the 10 percent capital-to-deposits ratio was important—1920 until 1939—the average capital-to-deposits ratio held by all US banks was 15.2 percent, so this minimum capital requirement may not have been binding for a large proportion of banks.

Following a significant investment by banks in US Treasury securities during World War II, federal supervisors (the comptroller of the currency, the FDIC, and the Federal Reserve) modified the denominator of the required capital-assets ratio so that bank-held Treasury securities—as well as cash holdings—were deducted from assets before calculating the ratio (Alfriend 1988, p. 28; Mitchell 1984, p. 19). Treasury security holdings were essentially risk-free, so it made little sense to require banks to hold capital against such holdings. This mid-1940s change to a capital measure that deducted banks' holdings of Treasury securities and cash from assets was an early, if short-lived, example of a risk-weighted assets (RWA) capital measure that appeared, in a more sophisticated manner, following changes to US capital requirements that came out of Basel I in 1989.

In the mid-1940s, regulators viewed a 20 percent ratio of equity-to-RWA sufficient, and in fact, in 1945 the average equity-to-RWA ratio for all US commercial banks was 25 percent.[6,7] The Federal Reserve's RWA-based capital requirement was made more sophisticated with a change in 1952 that applied different capital requirements—with higher capital for more risky assets—to various categories of assets. In 1956, the Federal Reserve's capital ratio was again modified along several dimensions, including the addition of capital for some off-balance-sheet items (Mitchell 1984, p. 19; Alfriend 1988, p. 28, Wall 1985, p. 10). Baer and McElravey (1992, footnote 2), however, argue that the Fed's RWA capital requirement was not "seriously enforced."

While in the 1950s the federal banking supervisors (the Federal Reserve, the FDIC, and the comptroller of the currency) maintained similar capital requirements, in the 1960s and 1970s differences between the various supervisors developed. For example, the comptroller dropped its focus on RWAs in the 1960s, and the regulators disagreed on how to measure capital. The Fed defined capital as equity plus reserves for loan losses, while the other two regulators counted certain types of debt as capital (Alfriend 1988, p. 29).

As can be seen in Figure 1, the banking industry, in aggregate, experienced a continuing downward trend in its equity-to-assets ratio. Specifically, the ratio fell from 58.3 percent in 1843 to 5.5 percent in 1945.[8] Afterward, this ratio increased in the late 1940s and 1950s, peaked in 1963, and then declined fairly steadily until 1979.

In 1981, the federal agencies focused on increasing bank capital levels and did so in a coordinated way (Wall 1985, p. 5). This focus was driven in part by declining capital ratios at the largest banking organizations in the face of growing international and domestic risks (Tarullo 2008, p. 36). All three federal agencies agreed on similar numerical capital standards of 5 percent capital-to-assets (meaning total balance sheet assets, not RWA assets) for large banks ($1 billion to $15 billion in assets) and 6 percent for smaller (community) banks. Multinational

[6] Mitchell (1984, p. 19) discusses the 20 percent RWA ratio requirement.

[7] Treasury securities increased from 19 percent of bank assets in 1940 to 56 percent in 1945. In 1945, aggregate commercial bank total assets were $157.6 billion. Cash and due from balances accounted for $34.3 billion of these assets, Treasuries were $88.9 billion, and total equity capital was $8.6 billion. From FDIC, Historical Statistics on Banking, Commercial Banks https://www5.fdic.gov/hsob/SelectRpt.asp?EntryTyp=10&Header=1.

[8] Figure 1 ratios are calculated by dividing the aggregate amount of total equity for all banks by the aggregate amount of total assets.

Figure 1 US Bank Equity/Assets Ratio 1834-2017

Notes: Sources: 1834–1933 data from Bureau of the Census; 1934–2017 data from Federal Deposit Insurance Corporation (2018).

banks (over $15 billion) faced a 5 percent minimum capital-to-asset standard starting in 1983 (Alfriend 1988, p. 30).

In a February 1983 federal appeals court ruling, supervisors' authority to enforce capital rules on banks was called into question when that court argued, at least in this case, that capital weakness alone, as measured by capital ratios, was not sufficient justification to impose a cease and desist order on a bank (First National Bank of Bellaire v. Comptroller 1983, p. 8-9). In November 1983, Congress responded to this court ruling by granting clear authority over bank capital levels to the federal banking supervisors in the International Lending Supervision Act of 1983 (ILSA).[9]

[9] That act accorded federal supervisors "the authority to establish ... minimum level[s] of capital for a banking institution" and authorized the supervisors (called "agencies" in the act) to "issue a directive to a banking institution that fails to maintain

While the federal supervisors gained clear enforcement authority for capital requirements from the ILSA, the Federal Deposit Insurance Corporation Improvement Act of 1991 (FDICIA) went a step further. This act established a "prompt corrective action" structure, setting tripwires whereby supervisors are required to undertake, without delay, progressively more severe actions as a bank's capital declines below "Adequately Capitalized" into progressively lower capital ratio categories: "Undercapitalized," "Significantly Undercapitalized," and "Critically Undercapitalized" (see Figure 4 for the current minimum capital ratios for each category). FDICIA mandates certain supervisory actions as a bank's capital declines into lower categories, including: heightened supervisory monitoring; restrictions on bonuses and raises to executives; and any acquisitions or new branch formations require prior supervisory approval. FDICIA also dictates that if a bank's equity-to-assets ratio of capital falls below 2 percent, supervisors must, within ninety days, place the bank in receivership or conservatorship, with few exceptions. (Spong 2000, p. 90-94; and Federal Deposit Insurance Corporation Improvement Act 1991, Section 131(c)(3)(B)(i)).

Beyond its clear grant of authority over capital requirements to federal supervisors, the ILSA also contained language supporting ongoing US participation in efforts to adopt international standards of bank supervision, including more uniform international capital standards.[10]

Efforts to increase the uniformity of bank supervision internationally, under the auspices of the *Basel Committee*, had begun in the mid-1970s, well before ILSA's enactment. Originally named the Committee on Banking Regulations and Supervisory Practices, the Basel Committee was formed in 1974 by the heads of the central banks of the Group of Ten countries. It now includes representatives from twenty-eight countries and is typically referred to as the *Basel Committee on Banking Supervision* (BCBS). The creation of the committee was driven by a number of disruptions in international financial markets caused by failures of important internationally active banks, particularly the June 1974 failure of the West German bank Bankhaus Herstatt (Bank for International Settlements 2018, p. 1). The committee is headquartered at

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capital at or above its required level... Such directive may require the banking institution to submit and adhere to a plan acceptable to the appropriate Federal banking agency describing the means and timing by which the banking institution shall achieve its required capital level" (Public Law 98-181, November 30, 1983, section 908).

[10] Specifically, ILSA stated that the "Chairman of the Board of Governors of the Federal Reserve System and the Secretary of the Treasury shall encourage governments, central banks, and regulatory authorities of other major banking countries to work toward maintaining, and where appropriate, strengthening the capital bases of banking institutions involved in international lending." (Public Law 98-181, November 30, 1983, section 908).

the Bank for International Settlements in Basel, Switzerland, and held its first meeting in February 1975. The BCBS's focus is most directly on internationally active banks and their cross-border supervision.

2. BASEL I REINTRODUCED RISK-WEIGHTED ASSETS AND INCLUDED OFF-BALANCE-SHEET EXPOSURES

One of the most significant early decisions of the BCBS was a multinational agreement on minimum capital standards, the Basel Capital Accord (later called Basel I)—published in final form in 1988. The accord was motivated by the Latin American debt crisis of the early and mid-1980s and the shrinking capital ratios of internationally active banks. It called on accord participants to require banks in their countries to hold a minimum of 8 percent capital to RWA. Banks were to meet this standard by the end of 1992 (Bank for International Settlements 2018, p. 3). Prior to the adoption of the accord, in 1986 US bank supervisors had proposed, but not implemented, a return to the RWA standards that also accounted for off-balance-sheet exposures. In 1987, US and British authorities worked together on RWA and off-balance-sheet-based capital standards (Alfriend 1988, p. 30).

RWA standards were seen as addressing a weakness in simple capital-to-assets standards: they were insensitive to asset riskiness. Bank A with very safe assets (for example, mostly Treasury securities and loans to only the most credit-worthy borrowers) and a 5 percent capital-to-assets ratio is much less likely to face financial problems than Bank B with the same 5 percent ratio but more risky assets (for example, mostly loans made to developers of speculative properties); nevertheless, the risky bank is allowed to hold the same amount of loss-cushioning capital as the less risky bank under a non-RWA capital-to-assets standard.

The Basel RWA standard categorized assets into five groups (0, 10, 20, 50, and 100 percent risk weights) based upon riskiness of the assets (Bank for International Settlements 1988, p. 8).[11] For example, cash and government debt securities were placed in the lowest risk group, and unsecured loans made to commercial firms were placed in the highest risk group. The lowest risk asset group received a weight of zero (meaning no capital need be held against these assets). The two next riskiest groups received a 10 percent weight and a 20 percent weight, in turn. With a 5 percent capital requirement for assets with a

[11] As implemented in the US in 1992, the 10 percent risk category was not used. See Board of Governors of the Federal Reserve System (1989, p. 4207-08, 4214); and US Department of the Treasury (1989, p. 4180-81).

Figure 2 US Minimum Capital Requirement Ratios Before Basel III

%	Immediately Pre-Basel	Basel I and Basel II
CET1/RWA		
Tier 1/RWA		4
Total Capital/RWA		8
Tier 1 Leverage Ratio		3 or 4**
Total Capital Leverage Ratio	6*	

Notes: *In 1985, the Federal Reserve adopted a 6 percent minimum Total Capital Leverage Ratio, meaning the ratio of total capital to total assets, for all banks and BHCs it supervised (Alfriend 1988, p. 30). In addition to the Total Capital Leverage requirement, in 1985 there was also a 5.5 percent "primary capital" leverage requirement. Primary capital was broader than Tier 1 capital under Basel I–III (primary capital included reserves for loans losses, for example) but narrower than the 1985 definition of total capital. **Tier 1 to quarterly average total assets. Three percent for BHCs with a composite strength rating of 1, 4 percent otherwise. From Bank of New York Mellon Corporation (2007), p. 8; Basel II final rule, p. 69302 (footnote 27); and Citigroup (2009), p. 43.

50 percent weight, banks were therefore required to hold capital equal to 2.5 percent of these assets. The riskiest group of assets received a 100 percent weight, meaning banks were required to hold capital equal to 5 percent of the amount of such assets.

The Basel Accord standards also required banks to hold capital against off-balance-sheet (OBS) exposures. A line of credit is an example of such an exposure, whereby the bank commits to make a loan to a business or to an individual, which can be drawn upon whenever the business or individual chooses.

US supervisors published their final Basel I-based rules in January 1989. The rules included a two-year phase-in: December 1990 through December 1992 (Board of Governors 1989, p. 4186-221; and US Treasury Department 1989, p. 4168-84). As of December 31, 1992, all US banks and bank holding companies (BHCs) were required to maintain a minimum ratio of Tier 1 capital-to-RWA (including OBS) of 4 percent and total capital-to-RWA of 8 percent (see Figure 2). Tier 1 capital, the narrowest definition of capital at the time, was a new measure based on an internationally agreed-upon Basel definition. It consisted of common equity, certain perpetual preferred stock, and investments by outsiders in the stock of the bank's or BHC's subsidiaries ("minority interests"). Total capital was made up of Tier 1 capital plus Tier 2 capital, which included a limited amount of the banking organization's reserves for loan losses, some additional preferred stock not allowed in Tier 1, and certain debt instruments with equity-like features such as unsecured perpetual debt.

Supervisors retained leverage ratio (non-RWA ratio) minimums in addition to Basel I's RWA standards (see Figure 2). They list two justifications: 1) RWA measures address credit risk, "but there are a number of other banking risks not addressed—e.g. interest rate risk, operational risk and asset concentrations"; and 2) with zero risk weights on some assets, banks could lever up considerably in a RWA-only capital regime (Board of Governors 1989, p. 4193; and US Treasury Department 1989, p. 4171).[12]

Comparing US capital requirements prior to Basel I with those implemented by Basel I-based requirements is difficult because Basel I added RWA requirements and modified the leverage ratio requirement. Nevertheless, it seems clear that bank capital, at least as measured by the simple equity/assets leverage ratio, began to increase as the US Basel I requirements began to take effect (Figure 1).

3. BASEL II MODERNIZED RISK CATEGORIES FOR THE LARGEST BANKS

While the Basel I RWA capital measure was a more risk-sensitive measure of capital than the simple equity-to-asset (leverage) measures that predominated in the early 1980s, supervisors viewed the five (four in the US) invariant (from bank to bank) risk categories as being too blunt and replaced them, for the largest banks and BHCs, with "Basel II" requirements in the mid-2000s. Basel II took greater account of differences in banking organization riskiness by including more detailed risk measurements of assets and OBS exposures—the denominator of

[12] Gambacorta and Karmakar (2016) explore the advantages and disadvantages of leverage versus RWA-based capital ratios.

the required capital ratios. Basel II left the numerator unchanged from Basel I.

As implemented by US banking supervisors, Basel II was meant to improve on Basel I by requiring large, internationally active banking organizations (banks or BHCs with assets over $250 billion or at least $10 billion in foreign exposures) to provide data describing the characteristics of individual assets or groups of assets. These data were fed into a formula, created by supervisors, which converted the data into requisite capital holdings.[13] The required data go beyond simple amounts of various types of assets (and OBS exposures) and include information on the expected losses that might be generated by the assets, as determined by the individual banking organization's risk-estimating models. Of course, supervisors were unwilling to simply take organizations' word for the riskiness of assets, so Basel II also emphasized supervisory examination of banking organizations' risk-measurement systems. Further, the US Basel II rules expanded large organizations' public disclosures of risk measures in the hopes that market oversight would encourage appropriate risk-taking. (Board of Governors 2007; Bank for International Settlements 2018, p. 4-5; US Government Accountability Office 2014, p. 7-8).

Final Basel II capital rules for large US organizations were published by the federal supervisors on December 7, 2007, took effect on April 1, 2008, and would be phased in by organizations over a period of years.[14] Basel II, at least for some of the covered banks and BHCs, was thought to have the potential to lower total capital holdings, which was a concern for supervisors and other observers, so that the multiyear phase-in period involved limits on the amount by which an organization's capital could decline. Further, these organizations were required to meet minimum leverage ratios and the minimum requirements, for bank subsidiaries, established by FDICIA.

For banking organizations smaller than the $250 billion cutoff in the US Basel II rule, the Basel I risk weights remained in place (called *standardized approach* in contrast to the *advanced approaches* for banks above the $250 billion cutoff).[15] The major difference between the standardized and advanced approaches is that the standardized approach

[13] The supervisor-created formula can be found at US Department of the Treasury (2007), p. 69411.

[14] The December 7, 2007, US Basel II rules can be found at US Department of the Treasury (2007).

[15] See for example, BB&T Corporation (2009), p. 78, and BB&T Corporation (2010), p. 87, which note that in this standardized approach ($157 billion in assets as of 2010) BHC's RWAs are calculated by assigning each "asset class ... a risk-weighting of 0%, 20%, 50%, or 100% based on the underlying risk of the specific asset class," abiding by Basel I-based RWA calculation methods.

did not gather information from internal risk models, which meant that smaller organizations were not required to create such models, unlike the larger organizations.

As can be seen in Figure 2, Basel II did not change the minimum capital ratios compared to Basel I. Its focus was on the method of calculating RWAs, the denominator of the nonleverage ratios in the figure; and in fact, changed RWA denominators only for the largest banking organizations. Therefore, Basel II had a limited effect on capital requirements for the broad swath of organizations. Only with changes made following the financial crisis and the resulting Basel III shifts were requirements altered in major ways for all organizations, compared with Basel I.

4. POSTCRISIS CAPITAL REQUIREMENTS

Following the financial crisis of 2007–08, global bank supervisors strengthened capital requirements by: 1) tightening the elements that count as capital (the numerator of capital ratios); 2) revising the ways that bank risks are measured (the denominator of capital ratios); and 3) requiring that higher ratios be met, at least when all buffers and surcharges are counted. The BCBS released new Basel capital standards, "Basel III," in December 2010 (Bank for International Settlements 2010). US legislators included in the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (DFA) requirements that US supervisors tighten capital requirements, and in 2013, US supervisors developed requirements that conformed with the Basel agreement standards as well as those in the DFA. Figure 3 provides a summary, in table form, of the major capital requirements in place after these changes.

The new US capital requirements apply to all banks—no matter their asset size—and to BHCs with assets greater than $1 billion (US Department of the Treasury and the Federal Reserve System 2013, p. 62151).[16] BHCs smaller than $1 billion are not required to meet the new capital standards, but their depository institution subsidiaries are. The logic of focusing only on the depository institution subsidiaries of small BHCs is that such BHCs are likely to have few, if any, activities outside of their bank subsidiaries and therefore carry little risk other than the ones found in these subsidiaries. Additionally, the relevant federal banking regulations state that if a small BHC has a significant

[16] In April 2015, the Board of Governors announced that it was increasing the BHC size cutoff (originally specified in October 2013 in Regulation Q) from $500 million to $1 billion in response to legislation enacted in December 2014. See: https://www.federalreserve.gov/newsevents/pressreleases/bcreg20150409a.htm.

Figure 3 Summary of Main Basel III/DFA Capital Requirements

		CAPITAL REQUIREMENTS			TLAC REQUIREMENTS
SUBSET OF FIRMS TO WHICH IT APPLIES		< \$250 B	> \$250 B	GSIBs (currently all >\$250 B)	
Measure of capital					
RISK-BASED	CET1	$\frac{CET1}{RWA}$ $\geq k_0 + CCB$ $= 4.5 + 2.5$	$\min\left\{\frac{CET1}{RWA}, \frac{CET1}{AARWA}\right\}$ $\geq k_0 + CCB + CCyB$ $= 4.5 + 2.5 + 0$	$\min\left\{\frac{CET1}{RWA}, \frac{CET1}{AARWA}\right\}$ $\geq k_0 + CCB + CCyB + GSIB$ $= 4.5 + 2.5 + 0 + 1.5$	N/A
	T1 (CET1 + AT1)	$\frac{T1}{RWA}$ $\geq k_1 + CCB$ $= 6 + 2.5$	$\min\left\{\frac{T1}{RWA}, \frac{T1}{AARWA}\right\}$ $\geq k_1 + CCB + CCyB$ $= 6 + 2.5 + 0$	$\min\left\{\frac{T1}{RWA}, \frac{T1}{AARWA}\right\}$ $\geq k_1 + CCB + CCyB + GSIB$ $= 6 + 2.5 + 0 + 1.5$	$\min\left\{\frac{T1 + qual.debt}{RWA}, \frac{T1 + qual.debt}{AARWA}\right\}$ $\geq tlac_1 + CCB + CCyB + GSIB$ $= 18.0 + 2.5 + 0 + 1.5$ • Buffers must be CET1 • Minimum debt requirement: 6 + GSIB
	T1 + T2 (TOTAL CAPITAL)	$\frac{T1 + T2}{RWA}$ $\geq k + CCB$ $= 8 + 2.5$	$\min\left\{\frac{T1 + T2}{RWA}, \frac{T1 + T2}{AARWA}\right\}$ $\geq k + CCB + CCyB$ $= 8 + 2.5 + 0$	$\min\left\{\frac{T1 + T2}{RWA}, \frac{T1 + T2}{AARWA}\right\}$ $\geq k + CCB + CCyB + GSIB$ $= 8 + 2.5 + 0 + 1.5$	N/A
LEVERAGE RATIOS	T1 (CET1 + AT1)	$LR = \frac{T1}{A}$ $\geq r$ $= 4$	$SLR = \frac{T1}{TE}$ $\geq r$ $= 3$	$SLR = \frac{T1}{TE}$ $\geq r + B$ $= 3 + 2$	$SLR = \frac{T1 + qual.debt}{TE}$ $\geq r + B$ $= 7.5 + 2$ • Buffer must be T1 • Minimum debt requirement: 4.5%

Notes: In the > \$250 B and GSIBs columns, T1 means Tier 1 capital, T2 is Tier 2 capital, TE is total exposures, AT1 is additional Tier 1 capital (meaning items that count as part of Tier 1 capital but not as part of the narrower CET1 capital), RWA means standardized approaches RWA, and AARWA is advanced approaches RWA.

amount of activities outside the bank subsidiary (and therefore risks outside of the bank), that BHC may become subject to BHC-level capital requirements.[17]

One important principle underlying the 2013 US capital regulations is that they should increase in complexity and detail as the size of the institution increases (and similarly, require less complex analysis and detail from smaller institutions). Two factors seem to motivate this principle. First, the largest institutions face the most complex risks (e.g., hedging, complicated derivatives exposures, and brisk trading

[17] The regulations addressing small BHCs with significant activities outside of the bank subsidiary are found in two locations. First, the Federal Reserve's Regulation Q—adopted in July 2013 but updated through amendments since. The up-to-date version is Board of Governors (2018a), and the section relevant for small BHCs is Section 217.1(c)(ii). Further relevant discussion is also found in Board of Governors (2015a), Section 1 of Appendix C to Part 225.

activities), and their requirements must be detailed and sophisticated to account for as much of this risk as possible; smaller institutions' risks are less difficult to measure (generally, lending and securities holdings). Second, the largest institutions engender the greatest moral hazard risks, so they should face the most intense focus; small institutions can fail without producing economy-wide concerns (and many small banks were allowed to fail during the last crisis and during financial difficulties in the 1980s and 1990s), while a number of large, troubled financial institutions were propped up during the recent crisis. As a result of this principle, the highest capital requirements, and the ones requiring the most detailed input from the institutions themselves, are those borne by the largest and most complex institutions; for example, additional capital charges and reporting requirements are imposed on the eight US Global Systemically Important Bank Holding Companies (GSIBs), which are the largest and most complex US BHCs.[18]

Another feature of the new capital regulations is the broad application of capital *buffers* for banks and BHCs. Buffers are required amounts of capital above specified minimum ratios. For example, as will be discussed in more detail below, banks and BHCs must hold common equity Tier 1 (CET1) capital at least equal to 4.5 percent of their RWAs. But beyond this amount, they must also hold an additional *capital conservation buffer* (CCB) amount of CET1 capital equal to 2.5 percent of RWA. This buffer amount acts as a tripwire, requiring mandatory banking organization action if the organization's capital lies between 7.0 percent of RWA (4.5 plus 2.5 percent) and 4.5 percent; the organization must begin to shrink its dividend payments to shareholders and bonus payments to senior managers as the organization's capital declines below 7.0 percent. Limiting dividend and bonus payments will naturally tend to rebuild capital, given that earnings that are not paid out as dividends or bonuses become retained earnings, adding to capital. These buffers, which apply to banks **and** BHCs, therefore, can be thought of as performing a role similar to the one played by FDICIA's prompt corrective action (PCA) requirements,

[18] The principle that more stringent requirements should be imposed on the largest and most systemically important institutions was a key feature of the Dodd-Frank Act (for example, Section 165), which required "more stringent" supervisory standards for the largest banking organizations. This same principle also underlies the October 31, 2018, Board of Governors proposals to "more closely match the regulations for large banking organizations with their risk profiles." Board of Governors Chairman Jerome H. Powell emphasized this strategy when explaining the proposals: "The proposals would prescribe materially less stringent requirements on firms with less risk, while maintaining the most stringent requirements for firms that pose the greatest risks to the financial system and our economy" (Board of Governors of the Federal Reserve System 2018e).

which apply only to banks.[19] The buffers automatically force actions that help to rebuild the capital strength of the BHC, just as the PCA requirements compel supervisors to take actions to force a bank to limit certain actions, and take other actions, with the intention of rebuilding the bank's capital strength.

5. NEW CAPITAL RATIOS

A New, More Narrow Numerator

The 2013 capital regulation put in place a new, narrower measure of capital, CET1 capital for banks (and for BHCs). CET1 includes common stock, retained earnings, and two more minor items of capital: certain minority interests and certain accumulated other comprehensive income (AOCI). As discussed earlier, "minority interests" are investments by outsiders in the stock of the bank's or BHC's subsidiaries. AOCI is "unrealized gains and losses on certain assets and liabilities that have not been included in net income," for example gains and losses on available-for-sale assets (US Department of the Treasury and the Federal Reserve System 2013, p. 62024). Previously, the narrowest definition of capital was Tier 1 capital, which remains in place. Tier 1 capital is similar to CET1, but it adds certain types of preferred stock that CET1 excludes.

New Denominators

The new US capital regulation also made changes to the denominator of the capital ratio for banks. For advanced approaches institutions, RWAs must be calculated in two ways, and the method that produces the lower ratio must be compared to the minimum requirement to determine if the organization is meeting capital requirements. The two methods are the *standardized* RWA calculation, whereby set weights are multiplied by specified categories of assets (such as: 0 percent for cash and certain government-issued or government-guaranteed debt instruments; 20 percent for exposures to US depository institutions; 50 percent for certain residential mortgage debt securities; and 100 percent for corporate debt and loans), and the *advanced approaches* RWA calculation.[20] Under the new capital rules, the advanced approaches method

[19] See Prompt Corrective Action provisions found in Section 38 (and especially subsection (b)) of FDICIA.

[20] Standardized and advanced approaches RWA calculations are discussed at length in the Federal Reserve's Regulation Q (Board of Governors 2018a): for standardized approach see Subpart D; for advanced approaches see Subparts E and F. The so-called

is largely the same as the method (discussed earlier) introduced in the US in response to Basel II, and the standardized approach is similar to that introduced in the US following the Basel I approach. However, the standardized approach under the new (2013) capital rule contains many more risk weight categories than the four categories found in the earlier Basel I-based RWA approach (Davis Polk 2016). Banks that are not advanced approaches banks, *standardized approaches banks*, measure RWA using only the standardized method.

These new capital ratio requirements (the CET1 numerator and the new advanced approaches and standardized denominators), once in place, became the new prompt-corrective action (FDICIA) rules for banks (see Federal Deposit Insurance Corporation Improvement Act 1991, Section 131(d)-(h), and Code of Federal Regulations 1998, (a)-(c)). FDICIA authorized supervisors to establish the capital ratios, and the levels of these ratios, to be used in the PCA enforcement regime (greater strictures imposed as a bank's capital declines from "Adequately Capitalized" to "Undercapitalized" and so on). Banks must meet or exceed all ratios specified in a row in Figure 4. Beyond banks, BHCs also must meet all of the risk-weighted capital ratio amounts in the "Adequately Capitalized" row of Figure 4 to be considered sufficiently capitalized under the 2013 capital regulation (Board of Governors 2018a, Section 217.10(a)).

"Collins Amendment" to the DFA—Section 171—is responsible for the requirement that advanced approaches institutions calculate these capital ratios by both the standardized and advanced methods and then meet requirements under both (meaning whichever calculation method produces the lower ratio is the binding calculation).

Figure 4 Prompt Corrective Action Requirements for Banks

Prompt Corrective Action Threshold	Risk-Weighted Capital Ratios			Leverage Ratios	
	Total capital	Tier 1 capital	Common Equity Tier 1 capital	All Banks	Supplementary Ratio: Advanced Approaches Banks Only
Well-capitalized	≥ 10%	≥ 8%	≥ 6.5%	≥ 5%	N/A
Adequately Capitalized	≥ 8%	≥ 6%	≥ 4.5%	≥ 4%	≥ 3%
Undercapitalized	< 8%	< 6%	< 4.5%	< 4%	< 3%
Significantly Undercapitalized	< 6%	< 4%	< 3%	< 3%	N/A
Critically Undercapitalized	Tangible equity (defined as Tier 1 capital plus non-Tier 1 perpetual preferred stock) to total assets ≤ 2%				N/A

Notes: Source: Davis Polk (2015, p. 23) and Prompt Corrective Action regulation found in Code of Federal Regulations (1998).

Total capital: The sum of tier 1 capital and tier 2 capital
Tier 1 capital: The sum of common equity tier 1 capital, certain perpetual preferred stock, some trust preferred securities, and certain minority interests (equity invested by outsiders in the organization's own subsidiaries)
Common Equity Tier 1 (CET1) capital: common stock instruments (plus any related surplus), retained earnings, accumulated other comprehensive income, certain minority interests
Tier 2 capital: certain perpetual preferred stock, some subordinated debt, some trust preferred securities, some minority interests, a limited amount of loan loss reserves
Total capital ratio: total capital divided by standardized total risk-weighted assets
Tier 1 capital ratio: tier 1 capital divided by standardized total risk-weighted assets
Common equity tier 1 capital ratio: common equity tier 1 capital divided by standardized total risk-weighted assets
Leverage ratio: tier 1 capital (minus amounts deducted from tier 1 capital under §217.22(a), (c) and (d)) divided by average total consolidated assets
Supplementary leverage ratio: tier 1 capital divided by the sum of (1) the mean of the on-balance sheet assets calculated as of each day of the reporting quarter and (2) the mean of the off-balance sheet exposures calculated as of the last day of each of the most recent three months, minus the applicable deductions under §217.22(a), (c), and (d).

Notes: Source: Board of Governors (2018a), which provides extensive details on these definitions.

Minimum Leverage Ratio for all Banks and Bank Holding Companies

The next-to-the-last column in Figure 4 lists the leverage requirement that must be met by all banks regardless of size. This leverage requirement is the ratio of Tier 1 capital to average total consolidated assets (daily or weekly averages over the quarter, depending on the size of the bank) (Federal Financial Institutions Examination Council 2018, p. RC-O-3; Board of Governors 2018a, section 217.10(a)(4)). This same ratio applies to all US BHCs except those with less than $1 billion in assets.

Supplementary Leverage Ratio

Advanced approaches banks are also subject to the *Supplementary Leverage Ratio* (SLR)—the last column in Figure 4 (see Board of Governors 2018a, section 217.10(c)(4)). This requirement took effect on January 1, 2018. The minimum for this ratio is 3 percent, lower than the 4 percent requirement for the leverage ratio—applicable to all organizations. While the numerator of the supplementary ratio is the same as the numerator for the simple leverage ratio ("All Banks" column)—Tier 1 capital—the denominator of the SLR is much more comprehensive. While the leverage ratio includes only on-balance-sheet assets, the SLR includes a broad compilation of off-balance-sheet exposures, such as derivatives and credit commitments (Davis Polk 2015, p. 22). This same ratio applies to all US advanced approaches BHCs as well. GSIBs face a higher SLR requirement (5 percent) than other advanced approaches firms: the 3 percent ratio plus an added 2 percent "leverage buffer" (Board of Governors 2018a, section 217.11(d); Citigroup 2017, p. 36; Goldman Sachs Group 2017, p. 72).

6. CAPITAL BUFFERS

Capital Conservation Buffer

Beyond the minimum capital requirements enumerated in Figure 4, the supervisors also impose an additional requirement on all banks and BHCs (except those BHCs with assets less than $1 billion): the capital conservation buffer (CCB).[21] This buffer acts as an early warning trigger device for any banking organization for which capital is declining. As mentioned earlier, the CCB requirement forces banks and BHCs to

[21] Note that while Figure 4 lists requirements for **banks**, the "Adequately Capitalized" row is also a minimum requirement for **BHCs**.

Figure 5 Payout Triggers for Capital Conservation Buffer Requirement

Capital Conservation Buffer	Maximum payout ratio (as a % of eligible retained income)
Buffer > 2.5%	No limit imposed under capital conservation buffer framework
2.5% ≥ Buffer > 1.875%	Up to 60% of eligible retained income
1.875% ≥ Buffer > 1.25%	Up to 40% of eligible retained income
1.25% ≥ Buffer > 0.625%	Up to 20% of eligible retained income
0.625% ≥ Buffer	No capital distributions or discretionary bonus payments allowed

Notes: Source: Davis Polk (2015, p. 28).

retain a higher and higher percentage of earnings (i.e., limit payouts to shareholders and bonuses to senior managers to a greater degree) as the organization's buffer holdings decline below 2.5 percent. The payout maximum begins at 60 percent (see Figure 5), so that the entity must retain 40 percent of its earnings, and declines to zero. The goal is to return the buffer to 2.5 percent, at which time the institution no longer faces a CCB-driven limit on its earnings payouts. The entity must hold this buffer amount above and beyond its "adequately capitalized" ratios (see Figure 4) of total capital, Tier 1, and CET1; should any of these ratios fall below the adequately capitalized ratio shown in Figure 4, plus 2.5 percent, the limits are imposed. Entities are also prohibited from paying bonuses without supervisory approval whenever their buffer falls below 2.5 percent (Board of Governors 2018a, sections 217.10-217.11). The CCB was phased in over a three-year period from January 2016 to January 2019 (Davis Polk 2015, p. 17, 19).

Countercyclical Buffer

Advanced approaches organizations are also subject to the Countercyclical Buffer (CCyB) (Board of Governors 2018a, section 217.11(b)). As with the CCB, this buffer must be met or the organization will face limits on distributions of earnings to shareholders and bonus payments (Board of Governors 2016, p. 24). Unlike other capital requirements, the CCyB requirement is meant to vary with the state of the overall economy. It is set by supervisors and can range from zero to 2.5 percent of RWA (Board of Governors 2018a, Section 217.11(b)(2)(iii)).

The decision by supervisors about where to set the CCyB amount will depend on such factors as "macroeconomic, financial, and supervisory information indicating an increase in systemic risk including, but not limited to, the ratio of credit to gross domestic product, a variety of asset prices, other factors indicative of relative credit and liquidity expansion or contraction, funding spreads, credit condition surveys, indices based on credit default swap spreads, options implied volatility, and measures of systemic risk" (Board of Governors 2018a, section 217.11(b)(2)(iv)). The CCyB amount will be increased "during periods when systemic risk is increasing" and reduced "as vulnerabilities diminish." The idea is that the CCyB could "moderate fluctuations in the supply of credit over time" (Board of Governors 2016, p. 4). The CCyB was created to respond to a DFA requirement that a countercyclical buffer be put in place that "increases in times of economic expansion and decreases in times of economic contraction" (DFA Section 616(a)). As of December 2018, supervisors were imposing a zero CCyB buffer requirement.

7. ADDED CAPITAL REQUIREMENTS FOR GLOBAL SYSTEMICALLY IMPORTANT BANK HOLDING COMPANIES

Because of the potential for widespread economic damage from the failure of the largest and most interconnected, internationally active banking organizations, such organizations—the GSIBs—are subject to additional capital requirements beyond those imposed on other advanced approaches institutions.[22]

GSIBs are those BHCs that have been determined, based on a systemic importance scoring methodology developed by the BCBS, likely to produce the greatest economic damage should they fail. In the US, all advanced approaches BHCs are scored. The score is based on a set of financial measures of on-balance-sheet and off-balance-sheet assets and liabilities, as well as measures of financial transaction flows, such as payments transfers. The set includes size ("Total Exposures," based not only on total assets, but also on off-balance-sheet exposures such as dollar amounts of derivatives, lines of credit, and loan commitments), a measure of how connected the organization is to other firms ("Interconnectedness"), and how difficult its activities might be to replace were it to fail ("Substitutability"), among others. Each measure is chosen because it is thought to correlate with how much economic harm the organization's failure might impose, so that the higher an organization's score, the higher its expected harm should the firm fail. Any US

[22] Jarque et al. (2018, p. 11-12) discuss the logic underlying the GSIB score and the GSIB capital surcharge and provide detailed descriptions.

advanced approaches BHC with a measure above a designated score is declared a GSIB and is subject to additional capital requirements.[23]

GSIB surcharge

One of the additional capital requirements imposed on GSIBs is the *GSIB surcharge*. This surcharge, which is really just a buffer applicable only to GSIBs, is calibrated so that it should just offset the additional harm the failure of these large, interconnected firms would impose, compared to non-GSIB organizations. The idea is that the greater this buffer requirement, the lower the failure probability of the GSIB. If one thinks of the expected harm a GSIB might impose as a function of the probability of its failure and the harm given its failure, by lowering the probability, the expected harm can be reduced to something close to the same level as that of smaller, less interconnected non-GSIB organizations.

The surcharge was phased in between January 2016 and December 2018. When fully phased in, for US GSIBs the surcharge should range between 1.5 percent and 3.5 percent—common equity Tier 1 capital as a percent of RWA.[24] This requirement, like the capital conservation buffer and the countercyclical capital buffer, is enforced by limiting payouts to shareholders and senior managers (Board of Governors 2018a, section 217.11).

Total Loss-Absorbing Capacity

The other added requirement applicable to GSIBs is the Total Loss-Absorbing Capacity (TLAC) requirement. In December 2016, the Board of Governors adopted a final rule requiring that the eight US GSIBs maintain a specified minimum level of equity (as measured by Tier 1 capital) plus *loss-absorbing* (long-term) debt, the combination of which is called TLAC (Board of Governors 2017).[25] The Board of

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[23] For descriptions of the US GSIB designation test and GSIB surcharge, see: Jarque et al. (2018); Board of Governors (2018a, Sections 217.400-217.406); Board of Governors (2015b); and Passmore and von Hafften (2017). As of November 2017, when the latest list of international GSIBs was announced by the Financial Stability Board (see Financial Stability Board 2017), there were eight US GSIBs: Bank of America, Bank of New York Mellon, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, State Street, and Wells Fargo.

[24] Based on the author's review of 2017 annual reports or 10-K filings of all eight US GSIBs. These reports and filings all contained forecasts of fully phased-in (2019) GSIB surcharge ratios.

[25] The rule requires the GSIB to meet this ratio requirement with externally derived debt and equity—meaning debt and equity raised from outside the organization. The rule includes similar requirements for US-located, foreign-owned intermediate hold-

Governors' rule is similar to rules adopted in other countries through auspices of the BCBS and the Financial Stability Board (FSB) and the direction of the Group of 20 (G20) leaders (Board of Governors 2017, p. 8).

Under the US rule, TLAC must be no less than 18 percent, plus relevant buffers (CCB, CCyB, and the GSIB surcharge), of RWA **and** 9.5 percent of total leverage exposure (meaning on-balance-sheet assets, plus off-balance-sheet exposures).[26] Further, the rule requires the GSIBs to maintain an amount of long-term debt equal to at least 6 percent, plus the firm's GSIB surcharge, of RWA **and** 4.5 percent of total leverage exposure (see Figure 3). US GSIBs must meet the TLAC rule by January 1, 2019 (Board of Governors 2017, section I(A)). For all TLAC RWA-based ratios, GSIBs must calculate the ratio using both the advanced approaches and standardized approaches methods and use whichever ratio is lower to determine whether it has met the requirement.

Equity, as has been discussed, is first to absorb firm losses. If losses are large enough to consume equity, then in a bankruptcy or supervisory-required reorganization (such as a DFA Orderly Liquidation Authority reorganization) of a troubled GSIB, some or all of the TLAC debt could be converted to equity, reducing the value of liabilities and returning the GSIB, or at least its important subsidiaries, to solvency.[27] In this way, important GSIB subsidiaries—such as the bank, investment bank, and payments subsidiaries—could continue operating, minimizing the bankruptcy's damage to the overall economy.[28]

Long-term debt is the focus of the debt portion of the TLAC requirement because of the idea that long-term creditors are in a better position to have their debts converted to equity than short-term creditors. The TLAC requirement can only be met with debt that has a maturity of at least one year—and debt with a maturity of between one and two years counts toward the requirement only after a 50 percent discount. The process of converting the debt to equity in the troubled GSIB is likely to take some time (likely more than a few days), so that only after such a period could the now-equity holder get repaid by sell-

ing companies with assets exceeding $50 billion. The TLAC rule is contained within the Federal Reserve's Regulation YY (subparts G and P are wholly devoted to TLAC; sections 252.2 and 252.2 of Reg. YY contain short TLAC stipulations).

[26] Board of Governors (2018a), section 252.63.

[27] See Pellerin and Walter (2012) for a detailed comparison of bankruptcy versus Orderly Liquidation.

[28] In its "Approaches to Resolution" section, the Fed's October 2015 then-proposed TLAC rule provides a detailed explanation of how TLAC would be used in a GSIB insolvency to preserve the health of important subsidiaries (Board of Governors 2015c, p. 74928).

ing its equity shares in the securities market (perhaps for less than its original investment). But short-term creditors of financial firms, many of which have overnight maturities, are thought of as dependent on *immediate* repayment of their investment in financial firms in order for them to repay their own creditors on time. Should such creditors' repayments be held up for an extended period, their losses might spread to other financial firms, creating a system-wide problem (often called "contagion"). It is this concern about short-term creditors' need for timely funds availability (which is the reason they make short-term investments even though such investments typically pay lower interest rates) and contagion to other firms that drives the requirement that TLAC debt be long-term debt.

8. STRESS TESTS

Current banking law requires the Federal Reserve, in coordination with the other bank supervisors, to conduct annual stress tests of banking companies larger than $250 billion and "periodic" stress tests of companies with assets between $100 billion and $250 billion.[29] The required tests are meant to evaluate a company's capital under various economic scenarios.

In its stress tests, the Federal Reserve employs three scenarios: "baseline," "adverse," and "severely adverse." Essentially, the stress test requires covered BHCs to prove—via the test—that they could suffer a negative economic shock (of various levels of severity—the scenarios) and still maintain their required capital ratios. The baseline scenario is centered on current forecasts (but does not represent the Fed's own forecasts) of the likely state of the economy over the next several years and includes forecasts of various economic variables (such as quarterly GDP growth, the unemployment rate, interest rates, and house prices) in the US and internationally.

The adverse and severely adverse scenarios involve weaker economic conditions (as measured by many of the same variables) than the base-

[29] The initial stress test requirement was found in Section 165 of the Dodd-Frank Act of 2010. The DFA required the Board of Governors, along with the other bank supervisors, to conduct annual stress tests for BHCs with $50 billion or more in assets. In May 2018, this requirement was modified by the Economic Growth, Regulatory Relief, and Consumer Protection Act (Public Law 115-174), raising the size cutoff for required annual stress tests to $250 billion. Any US BHC that is declared a GSIB, regardless of size, is subject to annual stress tests under the revised law. Currently (based on March 31, 2018, financial reports), a $50 billion cutoff would have included forty-five US BHCs, while the new $250 billion cutoff includes fourteen. The Federal Reserve's rules are found in Board of Governors (2011).

line scenario.[30] For example, the 2018 severely adverse scenario examined the impact on BHC balance sheets of a recession that produces: quarterly GDP growth rates that decline precipitously in the US to a low of negative 8.9 percent; a significant decline in GDP growth rates in the euro area (down to negative 5.2 percent) and Japan (negative 11.4); a peak US unemployment rate of 10.0 percent; and a quarterly US growth rate of disposable income falling as low as negative 5.1 percent. The idea is that if the BHC can endure the hypothesized adverse and severely adverse scenarios and still meet its capital requirements, then in an actual future recession the BHC will be able to continue to provide necessary lending and payments services and not exacerbate the already weak economic conditions by reducing its performance of these functions. If the company is unable to absorb any losses produced by the scenarios and still meet requirements, its ability to pay out dividends to shareholders is restricted (Board of Governors 2018b, p. 9, 25).

Large banking organizations are subject to two types of stress tests: the Dodd-Frank Act Supervisory Stress Test (DFAST) and the Comprehensive Capital Analysis and Review (CCAR). Both involve projections of losses produced by various hypothetical stress scenarios, as described above. However, the DFAST and CCAR differ along one dimension: how dividend payouts during the forecast period are calculated. Under the DFAST, the test assumes that the banking company will pay out dividends at a rate equivalent to the firm's previous year's payout.

In contrast, the CCAR test involves individual banking firms specifying their planned dividends over the test period (nine quarters). The Federal Reserve requires firms to limit their payouts below the level the firm had planned, and included in its dividend plan, if the CCAR stress test indicates that its capital will fall below required minimums given the planned payouts (Board of Governors 2018b, p. iii, 9-10).[31] Following the stress test process, the Federal Reserve publicly announces results.

[30] A detailed description of the 2018 stress test scenarios can be found in documents linked in Board of Governors (2018d).

[31] In April 2018, the Board of Governors proposed, for comment, a change to its CCAR process—replacing the CCAR procedure whereby the Fed will object to a banking firm's proposed dividend payout plans following its stress test if the Fed's stress test indicates that the payouts would leave the firm with low capital ratios. Instead, under the proposal, the Fed would run its stress test and a buffer would be added to the firm's risk-weighted and leverage capital requirements equivalent to the amount by which the firm's capital declines in the Fed's stress test (Board of Governors 2018c, p. 2-3).

9. RECENT INCREASES IN BANKING COMPANY CAPITAL

Given the many revisions to the implementation of capital requirements made by supervisors in response to Basel II, Basel III, and the DFA, it is somewhat difficult to determine how much requirements have changed, or even in what direction, over the past fifteen years. Comparing Figure 2 and Figure 4 might cause one to imagine that capital requirements have increased some, but not precipitously, since Basel I requirements were put in place in the early 1990s. Specifically, the minimum adequate level of total capital/RWA has been unchanged since Basel I at 8 percent, while the Tier 1/RWA requirement was increased, from 4 percent under the US Basel I and Basel II requirements (Figure 2) to 6 percent now (Figure 4, "Adequately Capitalized" row), under the Basel III-based requirements. Once the various buffers are added—the CCB for all banking organizations and the GSIB surcharge for the largest banks—however, it seems clear that capital requirements have increased noticeably, at least since the financial crisis.

The data on actual banking organization capital holdings seem to support the idea that requirements have increased—though, of course, organization holdings can shift for reasons other than shifts in regulatory requirements. Since the 2007–08 financial crisis, banking organizations have boosted their capital ratios appreciably in comparison to the lows experienced during the crisis and to the years immediately prior to the crisis (see Figures 5 and 6).

Prior to the financial crisis, Figure 6 shows that, on average, for US banking institutions (BHCs plus banks not owned by BHCs), CET1 capital relative to risk-weighted assets hovered around 8.4 percent.[32] Beginning with the first quarter of 2007, the ratio began declining and ultimately fell to a low of 6.1 percent in the first quarter of 2009. After that, the ratio began to climb back to former levels and then well above. While not charted here, the Tier 1-to-RWA and total-capital-to-RWA ratios follow a comparable path.[33]

As the ratio in Figure 6 was declining during the financial crisis, RWAs were increasing at a pace similar to their growth over the pre-

[32] Note that while data on CET1 capital were not reported on bank financial reports until after the financial crisis, a similar capital measure, "Tier 1 Common Equity," (not to be confused with the somewhat broader measure, Tier 1 capital, which has been collected since Basel I), was derived from data that **were** available on earlier financial reports. See the notes on Figure 6 for further discussion.

[33] See Federal Reserve Bank of New York (2018) for charts of Tier 1 and total capital relative to RWA. For Figure 6, note that because of capital requirement rule changes and reporting requirement changes, the definitions of the numerator and denominator changed somewhat over the charted period, leading to small breaks in the series between 2014Q1 and 2015Q1.

vious five years. CET1 capital, however, flattened out starting in the first quarter of 2007, declined for several quarters in 2008, flattened again, and then began increasing in the third quarter of 2009. Therefore, the decline in the ratio, during the recession, was driven by both an increase in the denominator (RWA) of the ratio and a decline in the numerator (CET1 capital). The decline in CET1 was the result of losses suffered (for one reason, because of a significant increase in loan loss provisions in 2008) during several quarters of the crisis, as well as low but positive earnings in other quarters of the crisis. Quarterly losses reduce capital, and low earnings reduce retained earnings (additions to capital). These reduced earnings and losses along with increasing RWA led to a decline in the ratio of CET1 capital to RWA. (Federal Reserve Bank of New York 2018; Excel data file).

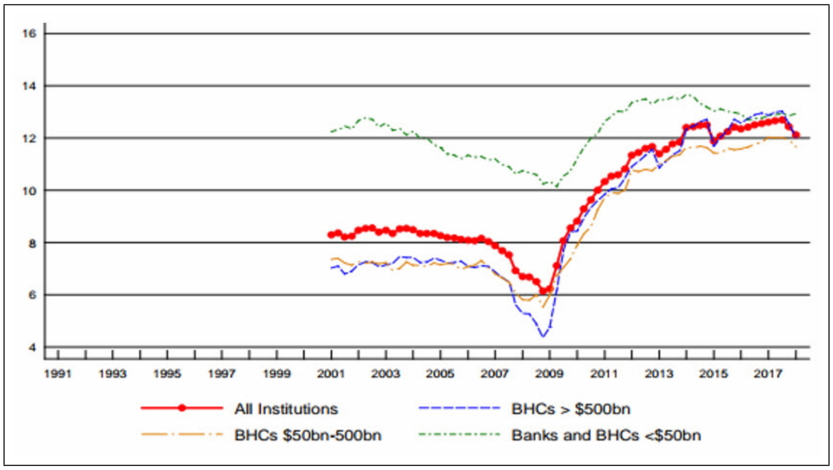
As earnings began to recover following the financial crisis, banking companies began to retain more earnings (adding to capital). They also received $313 billion in injections of capital from the government and gathered capital from private investors.[34] In total, between the first quarter of 2009 and the second quarter of 2014 (when the CET1 ratio in Figure 6 plateaued), banking companies added $752 billion to CET1 capital (Federal Reserve Bank of New York 2018; Excel data file). As a result, the CET1-to-RWA ratio increased significantly between 2009 and 2014, as can be seen in Figure 6. At the same time, new, higher capital requirements (once buffers are accounted for) were being implemented, encouraging additions to banking company capital holdings.

The category containing the largest banks shown in Figure 7, BHCs with assets over $500 billion (blue dashed line), as a group experienced the most rapid decline in their capital ratio of the four categories during the financial crisis. These large institutions also show the greatest increase in their capital ratio. Indeed, while prior to the financial crisis their capital ratio was considerably below the ratio for the smallest institutions (banks and BHCs with assets less than $50 billion, the dashed green line), the largest institutions now have a capital ratio commensurate with that of the smallest.

Figure 7 shows the **leverage ratio** for the same institutions shown in Figure 6. Specifically, the figure charts Tier 1 capital as a percent of average assets (assets measured at the beginning of the quarter plus assets measured at the end of the quarter, divided by two). It in-

[34] This figure ($313 billion) is the sum of the following TARP capital injection programs: Capital Purchase Program ($204.89 billion), Targeted Investment Program for Citibank and Bank of America ($40.0 billion), and the American International Group injection ($67.84 billion). See US Treasury Department (2018, p. 5.)

Figure 6 Common Equity Tier 1 Capital as a Percent of Risk-Weighted Assets

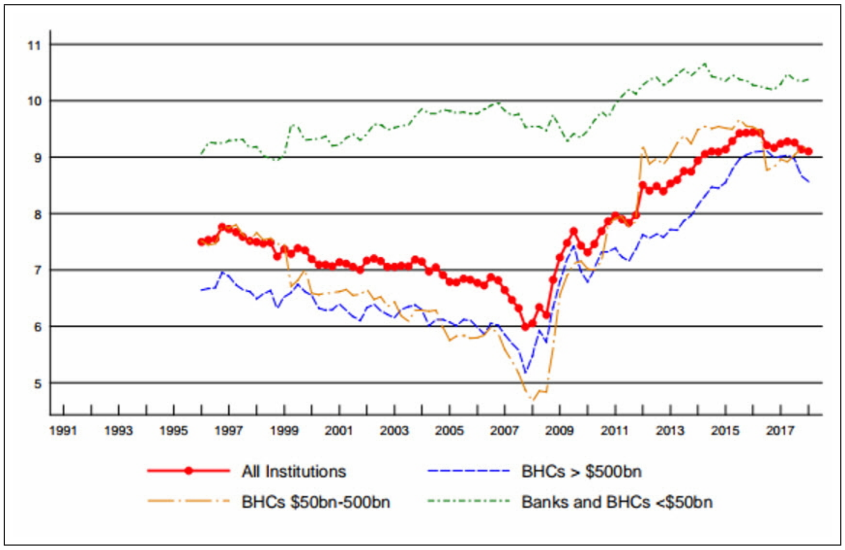


Notes: This figure charts Tier 1 Common Equity (as a percent of RWA) for the quarters before banks and BHCs began reporting the new Basel III-based measure CET1 capital, and it charts CET1 capital (as a percent of RWA) for the later quarters in which CET1 was reported in financial statements. Tier 1 Common Equity is derived from data available on bank and BHC financial statements and is meant to be similar to CET1. Over a period of time, between 2014 and 2015, CET1 began to be reported by banks and BHCs, first for the largest banking organizations and later for smaller banking organizations. Between 2014 and 2015, breaks in the series are driven by this shift from the derived Tier 1 Common Equity measure to the reported CET1 measure. The figure includes data for BHCs and non-BHC banks.

Source: Federal Reserve Bank of New York (2018).

volves no risk-weighting of assets and also includes no off-balance-sheet exposures in the denominator (in contrast, RWA, the denominator in Figure 6, includes off-balance-sheet exposures). This chart looks similar to Figure 6 in that the largest size category of institutions shows the deepest decline in their ratio during the financial crisis and the largest improvement afterward. One difference is that the largest institutions never reach the capital ratio of the smallest, indicating that risk-weighting assets (relevant for Figure 6 but not Figure 7) augments capital ratios more for large institutions than for small. Further, the under $50 billion category shows a smaller decline in their leverage ratio than their risk-weighted ratio (Figure 6) during the financial crisis.

Figure 7 Leverage Ratio: Tier 1 Capital as a percent of Average Total Assets



Notes: The figure includes data for BHCs and non-BHC banks.

Source: Federal Reserve Bank of New York (2018).

10. CONCLUSION

Following the financial crisis of 2007–08, policymakers made significant changes to bank and BHC capital requirements. Included were a new, more narrow, measure of capital, CET1, and a change to the way risk-weighted denominators are calculated for large banks and BHCs—requiring them to calculate their ratios using the standardized measure (similar to that introduced by Basel I) and the advanced approaches method (as introduced by Basel II). Stress tests, buffers, the TLAC requirement, a GSIB surcharge, and a special leverage requirement (supplementary leverage ratio) were also introduced in the postcrisis period. The emphasis of many of the changes was to more effectively control the risk-taking incentives of large banking organizations, the failure of which is considered the most worrisome for broad economic health, and which the financial crisis demonstrated as the most likely to receive government aid.

At the same time, policymakers were focusing on ensuring that the regulatory burden of the new capital requirements is minimized for smaller banking organizations, the failure of which inflict fewer costs on the economy. Small banks and BHCs are also less likely to receive government aid should they face failure. For example, this focus was an important motivation for the Economic Growth, Regulatory Relief and Consumer Protection Act, which increased the minimum size threshold for stress tests, among other changes.

While capital requirements have become a major element of the bank regulatory toolkit since the late 1980s and Basel I, we shouldn't be tempted to think that their genesis is with these modern changes. Instead, the origins of modern capital requirements extend back much further. Indeed, capital ratios were an important enough feature in banking regulation near the beginning of the twentieth century that they were included in the banking laws of a number of states. Likewise, supervisors understood the benefits of imposing risk-based capital requirements and accounting for off-balance-sheet risks as early as the 1940s.

Though policymakers have increased capital requirements and banks have increased their holdings since the financial crisis, the question of the appropriate amount of capital remains highly controversial. Some observers call for much higher capital requirements. For example, a 2017 proposal issued by the Federal Reserve Bank of Minneapolis calls for a large increase in the minimum common-equity-to-RWA ratio to at least 23.5 percent and of the leverage ratio to 15 percent (Federal Reserve Bank of Minneapolis 2017, p. 41). Others argue that raising the requirements can have serious offsetting costs that might exceed any benefits (Levkov and Peterson 2014). Along these lines, in 2017 the US House of Representatives passed the Financial Choice Act (which did not pass in the Senate), including a provision calling for reduced noncapital regulatory requirements for banks that maintain at least a 10 percent leverage ratio (equity/total leverage exposure). Therefore, while supervisors have now mostly fully implemented Basel III and Dodd-Frank capital requirements covering the spectrum of bank and bank holding companies, the current requirements are unlikely to be the last word.

APPENDIX

1. GLOSSARY

- Advanced Approaches Banks—Banks and BHCs with assets greater than $250 billion, which must calculate capital using more detailed (advanced) methods
- Basel I—The first multinational agreement on minimum capital requirements (under the auspices of the BCBS), published in final form in 1988
- Basel II—The second major multinational agreement on capital requirements as well as broader supervisory standards, published in final form in 2007
- Basel III—Third major international agreement, published in final form in 2010
- BCBS—Basel Committee on Banking Supervision, a committee of representatives of the largest countries, meant to increase uniformity of bank supervisory standards
- BHC—Bank holding company, a corporation that owns, or has a controlling interest in, one or more banks
- Buffer—required amounts of capital, above specified minimum ratios, that must be met to avoid restrictions on dividend and senior manager bonus payments
- CCAR—Comprehensive Capital Analysis and Review, a stress test of the largest banking institutions' ability to maintain strong capital even when subject to a hypothetical adverse economic (stress) scenario. The test is conducted by the Federal Reserve, focused on a future dividend payout plan specified by the institution
- CCB—Capital Conservation Buffer, a 2.5 percent additional capital requirement that must be held by all banks and BHCs
- CCyB—Countercyclical Buffer, applicable only to the largest institutions, this buffer is meant to vary with the state of the overall economy and is increased when supervisors view systemic risks as increasing
- CET1 Capital—the most narrow measure of capital; made up largely of common stock and retained earnings

- DFA—Dodd-Frank Wall Street Reform and Consumer Protection Act, enacted in 2010, included wide-ranging changes to bank regulation and supervision meant to reduce the chance of a repetition of the financial crisis of 2007-08

- DFAST—Dodd-Frank Act Supervisory Stress Test, a stress test of the largest banking institutions' ability to maintain strong capital even when subject to a hypothetical adverse economic (stress) scenario. The test is conducted by the Federal Reserve, focused on a future dividend payout plan determined by past dividend payouts by the institution.

- FDICIA—Federal Deposit Insurance Corporation Improvement Act of 1991, enacted in the wake of the savings and loan crisis of the late 1980s, required the supervisors to take prompt corrective action when a bank's capital begins to decline

- GSIB—Global Systemically Important Bank Holding Company (or Bank)

- ILSA—International Lending Supervision Act of 1983, required bank supervisors to establish minimum international lending standards and granted federal bank supervisors clear authority to establish and enforce capital standards, and called on the Fed and the Treasury to encourage other governments to strengthen capital requirements for their country's banks

- OBS—Off Balance Sheet; financial exposures that do not currently show up as assets or liabilities of the bank but nevertheless could produce income or expenses (and in some cases, assets or liabilities) in the future; examples are commitments to make future loans or derivative instruments such as swaps and options

- PCA—Prompt Corrective Action; a feature of the FDICIA requiring banking supervisors to take prompt action (within a specified number of days) when a bank's capital falls below required levels

- RWA—Risk-Weighted Assets; weighting assets by their riskiness in the denominator of capital ratios

- SLR—Supplementary Leverage Ratio, a measure of capital applicable to advanced approaches banks; the numerator is Tier 1 capital, and the denominator is on-balance-sheets assets plus a broad compilation of off-balance-sheet assets

- Standardized Approaches Banks—Banks and BHCs with assets below $250 billion, which calculate capital using less-detailed methods (compared with the advanced approaches banks)

- TE—Total Exposures, a measure of bank and BHC size, including total assets as well as off-balance-sheet exposures such as derivative and loan commitments

- Tier 1 Capital—A narrow definition of capital made up largely of common stock and retained earnings but also some preferred stock (excluded from the even more narrow CET1 capital)

- TLAC—Total Loss-Absorbing Capacity, applicable to GSIBs only; a broad measure of "capital" including Tier 1 capital and certain types of long-term debt (with maturities of at least two years, and a portion of long-term debt with maturities of between one year and two years)

- Total Capital—A broad definition of capital equal to the sum of Tier 1 capital and Tier 2 capital

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How Likely Is the Zero Lower Bound?

Thomas A. Lubik and Christian Matthes

During the course of the Great Recession and for long after, the Federal Reserve kept the main monetary policy rate at the zero lower bound (ZLB).[1,2] This policy was pursued in order to fight the deepest recession since the Great Depression and to support the budding recovery. The Federal Reserve finally abandoned its low interest rate policy and exited from the ZLB in December 2015 as the expansion gathered pace. It is now one of the longest on record in US economic history. Yet, given the length of the expansion and its recent strength, the level of the policy rate is arguably still low when compared with the historical experience.[3]

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[1] Strictly speaking, the Federal Reserve's key policy rate, the federal funds rate, was maintained in a range between zero and twenty-five basis points and never was actually at zero. However, the interest rate on excess reserves that the Federal Reserve paid to banks was set at zero. Other major central banks, such as the European Central Bank, the Bank of Japan, and the Swedish Rijksbank set policy rates to zero or even negative values. The label ZLB is thus shorthand for rates that are effectively zero.

[2] The ZLB is often taken to coincide with the ELB, or effective lower bound, but experience has shown that nominal policy rates can be negative for extended periods. For instance, the European Central Bank and the Swedish Rijksbank have maintained negative rates on excess deposits held willingly by banks in their reserve accounts. In that sense, the ELB is below the ZLB, but there is no consensus in the economics profession on how low nominal policy rates could go. For the purpose of this article, we assume, however, that the ELB and the ZLB coincide, since the Federal Reserve is unlikely to consider negative policy rates.

[3] One explanation of why the nominal policy rate is low is that with inflation expectations anchored at the Federal Reserve's target of 2 percent, the natural real rate of interest is lower than in prior expansions. There is substantial evidence (e.g., Lubik and Matthes 2015b; Laubach and Williams 2016) that the natural rate exhibits secular decline over the last thirty years, which limits how high the equilibrium policy rate can go.

Naturally, this raises the question of how likely it is that monetary policy will again be subject to the ZLB in the coming years. More specifically, policymakers may wonder when the current expansion might end and whether they may have to pursue accommodative policies, possibly in a preemptive manner. During contractions, the Fed has traditionally lowered policy rates and kept them low to support the recovery. However, when policy rates are already low during the expansionary phase, as is currently the case, this potentially limits the ability of the Fed to provide accommodation because of the presence of the ZLB. This might arguably put the Fed in a dilemma regarding the pace of interest rate increases.

On the one hand, the Fed could raise rates faster than is usually warranted in order to create more distance from the ZLB as insurance against the possibility that it might have to lower rates significantly to stem against a contraction. On the other hand, the Fed could go slower so as not to endanger a budding recovery and not face a contraction at all. At the same time, the likelihood of ZLB episodes is also central to debates about whether the Fed should replace its current 2 percent inflation target with either a higher target or a different framework. But all of these discussions center around the idea of insurance against being too close to the ZLB.

In this article, we therefore investigate the likelihood that the economy may be subject to the ZLB again. In this sense, we provide a quantification of the insurance aspect against the ZLB in terms of a forecast of that uncertainty. Specifically, we focus on the forecasting framework surveyed by Lubik and Matthes (2015a), which was previously applied to estimation of the natural rate of interest (Lubik and Matthes 2015b). We specify a time-varying parameter vector autoregressive model (TVP-VAR) for a set of key macroeconomic variables and estimate the model on the available data. Interpreting the model as an acceptable representation of the underlying structure of the economy and the effects of monetary policy, we then simulate the estimated TVP-VAR forward based on the estimated posterior distribution of its parameters. This generates a distribution of trajectories for macroeconomic outcomes, including the path of the federal funds rate (FFR), which we use as a monetary policy variable. From this distribution, we can then compute the probability that the interest rate will be at the ZLB in the future.

Our main result is that the probability of the ZLB is negligible over the next two years. It is only during 2022 that the probability rises above 5 percent. Depending on the specific interpretation of the ZLB probability, whether it is date-specific or horizon-specific, the probability rises at most to 15 percent by the end of the 2020s. While these numbers are not negligible, they do not appear large enough to cause undue alarm. We also find that the ZLB probabilities have declined over the last three quarters. Our main findings are based on data up to and including the third quarter of 2013, which saw robust growth. The same exercise with a sample ending in 2018Q1 yields longer-term ZLB estimates of around 25 percent while still being negligible at a short horizon. The strength of the recent data flow thus makes the ZLB less likely since the model incorporates the possibility of an ever-so-slight trend GDP growth shift.

As a robustness check and an assessment of the overall validity of our forecasting model, we also investigate how well the TVP-VAR has performed in the past, specifically during the Great Recession. To do so, we conduct a pseudo out-of-sample exercise where we carry out our forecasting exercise while conditioning on the parameter estimates at that point in time. The ZLB probabilities are computed in a like manner, that is, as if the subsequent data were unknown to the researcher. We find that right at the onset of the downturn, the model predicts the ZLB with a very high probability of 80 percent on account of the dramatic decline in real GDP growth. Going further out, however, and as the subsample expands, this probability drops to below 40 percent, even as the policy rate remains at the ZLB and has been there for a while.

This observation reveals a feature of the data that even a flexible nonlinear model such as the TVP-VAR has difficulty dealing with, namely reversion to the mean. In other words, the Great Recession and the subsequent ZLB period are such unusual events that the model has a tendency to discount their impact going forward. At best, this feature of the data is reflected in a wider distribution of the forward simulation that underlies the computation of the ZLB probabilities. In that sense, a shift in the ZLB probabilities observed in 2018 can be seen as evidence of an underlying trend shift.

Perhaps surprisingly, the question of how likely the ZLB is has not attracted much attention in the empirical macroeconomics literature, specifically the forecasting literature. While there is much research on the effects of the ZLB in traditional New Keynesian models, these studies are not forecast-based but instead study the probability of being at the ZLB generically. Perhaps closest to our exercise is Chung et al. (2012), who use several forecasting models used in the policy process, such as the Federal Reserve's own large-scale macroeconometric model FRB/US, two canonical New Keynesian dynamic stochastic general equilibrium (DSGE) models, and also a TVP-VAR closely related to ours. In a similar stochastic simulation exercise, they construct forecast densities based on data up to and including 2007Q4. None of the models, perhaps surprisingly least of all the TVP-VAR, include the ZLB in their 95 percent coverage region, which echoes some of our findings. However, they focus on this one base year only, whereas we compute densities for forty quarters out and also conduct a model validation exercise.

In a more recent study, Kiley and Roberts (2017) simulate both the FRB/US policy model and a standard DSGE model often used in the policy process with shocks drawn from estimated distributions over the 2000–15 period. They find that the ZLB probabilities are small, reaching at best 20 percent for levels of the natural rate at 3 percent, which is consistent with the natural rate forecast embedded in our model.[4] In a pseudo out-of-sample exercise for 2013 that is similar to ours, they also have the feature of mean reversion unless they strongly force the policy rule to follow the ZLB.[5]

We proceed as follows. In the next section, we discuss our empirical approach in more detail. We introduce our statistical forecasting model, a TVP-VAR, and then describe two alternative measures of the ZLB probabilities. Section 3 contains the results of the paper, including a pseudo out-of-sample exercise to assess the quality of the forecasting model. The final section concludes.

1. METHODOLOGY

We estimate the probability that the federal funds rate will be at or below the ZLB from a statistical model of the US economy. The first step of our analysis is therefore to develop a model that captures the behavior of key macroeconomic variables well, especially during previous ZLB episodes. Since an assessment of such probability involves a forecast, a desirable property of the statistical model is a good forecasting performance. For this purpose we use a TVP-VAR, which has become widely used for economic and policy analysis and is a flexible framework to address the kinds of issues discussed in this article.[6]

The advantage of a TVP-VAR is that it is a largely atheoretic time-series model, which absolves the researcher from taking a stand on the

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[4] See Lubik and Matthes (2015b) and updates thereof at: https://www.richmondfed.org/research/data_analysis.

[5] Jones (2017) finds similar results in a fully estimated DSGE model that accounts for possible trend breaks associated with the secular decline in the natural real rate of interest. He is able to match the data with a forward guidance policy rule.

[6] Doh and Connolly (2012) and Lubik and Matthes (2015a) provide an overview of the methodology and a step-by-step guide to its implementation. Examples of its use in the monetary policy process are discussed in Clark and Ravazzolo (2015) and Lubik and Matthes (2015b), while Canova and Gambetti (2009) and Lubik et al. (2016) detail some of its limitations.

deep, underlying relationships that govern the joint behavior of aggregate variables. Perhaps more importantly, a TVP-VAR can in principle capture nonlinear behavior in the underlying time series, such as the ZLB, where movements in the interest rate are capped by a lower bound of 0 percent, without specifying the precise source of the nonlinearity. TVP-VARs have also proved useful in forecasting because they allow researchers to distinguish between structural or long-lasting changes in the economy and shorter-term fluctuations in a consistent and transparent manner. The former affect trends and forecasts thereof, while the latter are often driven by changes in the volatility of shocks hitting the economy. Allowing for time variation in both elements of the model helps researchers differentiate these sources of aggregate fluctuations.

A TVP-VAR for the US Economy

We specify a TVP-VAR in quarterly data on real GDP growth, PCE inflation, and the federal funds fate, which are collected in a column vector y_t. We assume that the joint evolution of these variables is governed by the law of motion:

$$y_t = \mu_t + \sum_{j=1}^{2} A_{j,t} y_{t-j} + e_t. \tag{1}$$

μ_t is a drift term that can contain deterministic and stochastic components. It is of particular importance for capturing the changing trends in the variables, such as the decline of GDP growth over the last fifty years or the ZLB, which can be regarded as trend break in this context. The $A_{j,t}$ are conformable coefficient matrices that contain time-varying parameters, the evolution of which we detail below. e_t is a vector of residuals. We set the lag length equal to two, which is standard for quarterly data in the TVP-VAR literature (see Primiceri 2005). We can define $X_t' \equiv I \otimes (1, y_{t-1}'..., y_{t-2}')$ to provide a compact representation of the dynamics of y_t. We then rewrite equation (1) as:

$$y_t = X_t' \theta_t + e_t. \tag{2}$$

We assume that the law of motion for the time-varying parameters in the coefficient matrices $A_{j,t}$ is given by a random walk process:

$$\theta_t = \theta_{t-1} + u_t, \tag{3}$$

where u_t is a zero mean i.i.d. Gaussian process. We model the process for stochastic volatility by assuming that the covariance matrix of the one-step-ahead forecast error e_t can be decomposed as follows:

$$e_t = \Lambda_t^{-1} \Sigma_t \varepsilon_t, \tag{4}$$

where the standardized residuals are distributed as $\varepsilon_t \sim N(0, I)$. Λ_t is a lower triangular matrix with ones on the main diagonal and representative nonfixed element λ_t^i. Σ_t is a diagonal matrix with representative nonfixed element σ_t^j. The dynamics of the nonfixed elements of Λ_t and Σ_t are given by:

$$\lambda_t^i = \lambda_{t-1}^i + \zeta_t^i. \tag{5}$$

$$\log \sigma_t^j = \log \sigma_{t-1}^j + \eta_t^j. \tag{6}$$

We assume that all these innovations are normally distributed with covariance matrix V. In order to provide some structure for the estimation, we restrict the joint behavior of the innovations as follows (following Primiceri 2005):

$$V = Var\left[\begin{pmatrix} \varepsilon_t \\ u_t \\ \zeta_t \\ \eta_t \end{pmatrix}\right] = \begin{bmatrix} I & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix}. \tag{7}$$

S is further restricted to be block diagonal, which simplifies inference. We use a Gibbs-sampling algorithm to generate draws from the posterior. The implementation of the Gibbs-sampling approach used for Bayesian inference follows Del Negro and Primiceri (2015) and is also described in more detail in Lubik and Matthes (2015a).

A key choice for TVP-VAR modeling is how to set the prior. In order to achieve sharp inference, given the multiple sources of variation in TVP-VAR models, a researcher needs to impose restrictions on the relationship between the covariance matrices of the parameters. The trade-off, however, is that a too-restrictive prior may not leave room for the time-variation to appear. In our benchmark, we impose a typical choice of prior as recommended in Primiceri (2005). Specifically, we assume the following:

$$Q \sim IW(\kappa_Q^2 * 40 * V(\theta_{OLS}), 40), \tag{8}$$

$$W \sim IW(\kappa_W^2 * 2 * I, 2), \tag{9}$$

$$S \sim IW(\kappa_S^2 * 2 * V(\Lambda_{OLS}), 2), \tag{10}$$

where IW denotes the Inverted Wishart distribution. Priors for all other parameters are the same as in Primiceri (2005). For the prior hyperparameters κ_Q, κ_W, and κ_S, we use the values $\kappa_Q = 0.01$, $\kappa_W = 0.01$, and $\kappa_S = 0.1$.

Computing ZLB Probabilities

The probability that the economy will reach or fall below the ZLB in the future is based on a forecast of the joint evolution of the variables in the statistical model. This is not a point forecast but rather a collection of forecasts that detail all likely paths the economy will take given where it is now. The ZLB probability then simply captures how many times the interest rate will be at or below zero. In order to operationalize this idea, we proceed as follows. In the first step, we estimate the TVP-VAR over the entire sample period. Our posterior sampler delivers the posterior distribution of parameters for any point in the sample, which we will exploit later. We then fix the coefficients at their last estimated posterior mean and keep them fixed over the forecast horizon. This assumption is made for computational expediency as it does not require simulating paths of parameters. Recall that all coefficients in the model are varying over time, including the trends, the lag coefficients, and the parameters governing the volatility of the shocks. In the simulation exercise we do not draw from the innovation distributions of the TVP-VAR parameters as this would add an additional layer of uncertainty.

This approach is consistent with the idea of an unchanged forecast where the structure of the economy is not expected to change. This assumption seems reasonable as a baseline, especially in light of the fact that we model the evolution of parameters as random walks. In addition, it is a well-known drawback of TVP-VARs that because of all the moving parts uncertainty about forecasts is generally higher. Forecasting the paths of parameters as well would thus just compound this uncertainty. In that sense, there would be too much parameter variation to make the forecasts meaningful, or alternatively, current conditions would be uninformative about the future. We therefore choose to err on the side of sharper predictions. What we might miss are, at lower frequencies, changes in trend growth, as we have seen over the last decades for real GDP and the real rate of interest, and periods of excess volatility, such as we have seen during deep recessions and financial crises. At the same time, such events are notoriously difficult to forecast. We show an example of this and its implications for our exercise below.

Given this structure of the TVP-VAR, we produce forecasts over a ten-year horizon. The forecasts are such that for each future date we generate realizations of the shocks hitting the economy; that is, we draw from the estimated distribution of the innovations to the exogenous processes and record how they propagate through the economy. This generates sample trajectories of the model's endogenous variables that can be collected at every point in time as a distribution of likely outcomes. From this collection of sample paths, we can then compute the probability that the interest rate will be at or below the ZLB.

In principle, one can think of two alternative measures. The first gives an answer to the question: What is the probability that at a given point in time the FFR is forecast to be at or below zero? We measure this by counting how many times the interest rate is subject to the ZLB at a given date under all simulated trajectories. The ZLB probability is then found by dividing this count by the total number of simulations at the specific point in time. We label this measure 'unconditional' as it represents the marginal probability of being at the ZLB at a given time period. In terms of our forecasting exercise, it is a simple count of ZLB events at every point in time, normalized by the total number of forecast paths.

We also consider an alternative measure that we label 'conditional.' This measure represents the probability that the economy has been at the ZLB at least once up to and including the current period. It thereby takes into account the dependency of the ZLB episodes. As the forecast horizon increases, the count is accumulated. For instance, consider a trajectory of the FFR that is below zero in period $t+1$ and period $t+2$ and is above zero in period $t+3$. For the first, unconditional measure, we record a count of one, one, and zero, since the measure focuses on the ZLB episodes in any period. For the second, conditional measure, the count is one, one, one, since this hypothetical path features two incidences of a ZLB episode. In this case, the trajectory still enters the ZLB count in the last period since the given incidence of shocks resulted in a ZLB episode in prior periods and thus contributed to the overall "risk" of the ZLB. In this sense, it is a cumulative probability measure for the question at hand. From a policymaker's point of view, it conveys the information that even if a trajectory is not subject to the ZLB at a particular date, it may have been so in prior periods and may therefore have to be avoided. Naturally, the unconditional measure is bounded from above by the conditional measure.

2. THE PROBABILITY OF BEING AT THE ZLB

We report the key findings of this article in Figures 1 and 2, which report the two measures of the ZLB probabilities discussed above. We consider a forecast horizon of ten years at a quarterly frequency. The figures show the ZLB probabilities for three sample periods each, namely ending in 2018Q1, 2018Q2, and 2018Q3, respectively, but with the same start date, 1963Q1. The samples are real time in that we have used the data actually available to policymakers at that time. For the sample with the most recent data, up to and including 2018Q3, the figures show that for both measures the probability is essentially zero for one year out. It rises gradually toward a long-run level of 7 percent in the case of the unconditional measure in Figure 1 and around 13 percent for the alternative measure in Figure 2. As can be seen from the figures, the ZLB probabilities are rising over time. This stems from the fact that uncertainty is expanding as we forecast further out into the future and that the conditional probability is cumulative.

As discussed above, the probabilities shown in Figure 1 give policymakers an unconditional view that the ZLB may occur again in the future. From this perspective it indicates that there is less than a one in ten chance that in 2028 the economy will be in a situation where the FFR is again constrained at zero. Since the ZLB has been observed in the dataset, the model deems it likely to happen again, given the estimated historical patterns of shocks when extrapolated forward. This is irrespective of whether any trajectory has been at the ZLB before or not. The estimates in Figure 2 show a similar pattern with virtually zero probability for one year from now. It is then rising to a long-run level of close to 15 percent. The interpretation of this conditional measure is that in 2028 roughly one-eighth of all forecast trajectories of the federal funds rate will have hit the ZLB at some point, either only once or repeatedly.

The ZLB probabilities for the sample ending in 2018Q2 are essentially identical to the most recent sample, with the latter's unconditional probability slightly higher in the first half of the sample but slightly lower in the second half. In contrast, the ZLB probabilities for the 2018Q1 sample are considerably higher, rising to a long-run level of 15 percent in the case of the unconditional measure and around 30 percent for the other measure. Still, for one year out, the probability is effectively zero. This shift in the estimated ZLB probabilities is driven by the strong GDP growth data in the second and third quarters of 2018, which imply a higher forecast FFR path and thus a larger distance from the ZLB for all trajectories. Moreover, the stronger growth data may lead the model to reevaluate the underlying properties of GDP, which also support a higher FFR path. In addition, a stronger economy in 2018 reduces the likelihood of a recession in the near term, thus reducing the ZLB probabilities.

This discussion raises the question of how reliable the estimates of the ZLB probabilities are. The quality of the estimates rests crucially on how well the model captures past experiences, including the ZLB period during 2009–14. The future is, of course, uncertain, but we can get a sense of how well the TVP-VAR has performed in the past by conducting a pseudo out-of-sample forecasting exercise. We proceed as follows. As a starting point, we use the baseline estimated posterior distribution of parameters at different points in time. The posterior estimates of parameters at any point in time are a function of all available data—data at time $t + j, j \geq 1$ are generally informative about the parameter values in place at time t. Using this approach instead of a true out-of-sample exercise, where we would have to reestimate the model period by period, is computationally much more tractable but is naturally subject to the caveat that it is based on information that could not have been known at that time.[7]

We then perform the same forecasting exercise as discussed above. At each date we simulate the model forward using the posterior estimates of the coefficients, which are held fixed over the forecast horizon. We produce the same counts as in the prior exercise, namely how many times the interest rate is at or below the ZLB for each quarter. Figure 3 shows results from this exercise. We focus on four forecast horizons: one quarter ahead, four, eight, and then twenty. The horizontal axis in the figure denotes the period in which the forecast is made, while each panel reports results for a specific forecast horizon. The four panels in the figure depict the unconditional ZLB probabilities at the respective forecast horizons as they change over time.

The upper left-hand panel shows the one-step-ahead ZLB probability. For almost the entire sample period the probability is zero on account of high interest rates (and high inflation during the 1970s). This changes in early 2009 as this probability shoots up to 80 percent with the onset of the Great Recession. This is driven by the sharp decline in real GDP growth, which, given historical patterns embedded in the estimated model, prompts a sharp drop in the interest rate. The one-step-ahead forecast at the next data point drops to below 50 percent and hovers around 20 percent until 2015 with the start of the exit from the quantitative easing period. The ZLB probabilities during this period are punctuated by occasional spikes that line up with weak data on GDP growth and low inflation numbers.

Nevertheless, these estimates indicate one weak point of the TVP-VAR, namely that it exhibits something akin to mean reversion.[8] Despite having observed policy rates at zero for several years, the TVP-VAR continues to predict an immediate rise in rates and hence a low

[7] Another caveat associated with this exercise is that we use final data for the estimates. This presumes knowledge that policymakers at that time could not have had, as initial data releases are typically subject to measurement errors and later revisions. The TVP-VAR estimates thereby do not reflect the actual decision-making environment that policymakers faced, which can result in biased estimates of the implicit policy rule. Lubik and Matthes (2016) show that policymaking under this type of data mismeasurement can considerably affect macroeconomic outcomes.

[8] To be clear, the TVP-VAR does not per se exhibit mean reversion as the coefficients are modeled as random walk processes and the underlying data are allowed to be nonstationary. In that sense, there is no ergodic distribution, but this does not rule out a proper posterior distribution. In addition, in our forward simulation exercise, we are holding the coefficients fixed at their last estimated value. It can be seen from Figures 1 and 2 that the ZLB probabilities seem to stabilize. It is in that sense that we apply the moniker mean reversion.

ZLB probability. As outside observers, the persistence of a ZLB policy is apparent, not least from Federal Reserve communication; yet it is not straightforward to capture this feature in a statistical model.[9] Overall, this serves as a caveat for the findings above, namely that the TVP-VAR does not fully capture the underlying dynamics in the data.

The other three panels in Figure 3 show similar patterns. There is a spike of the ZLB probabilities at the onset of the Great Recession, which then settle at a lower level before dropping to almost zero with the beginning of the tightening period. What differs across panels is the time horizon along which the probabilities are estimated. As the horizon expands from one quarter ahead to twenty quarters, the initial ZLB probability drops. For instance, at five years out, the model implies a 50 percent chance that the economy will be at the ZLB. In that sense, the TVP-VAR captures the underlying ZLB dynamics reasonably well as it incorporates the sharp interest rate drop to fight the downturn and ascribes persistence to it.

Moreover, the same panel shows that the slowdown in growth observed around the middle of the 2000s translates into an increased ZLB probability. In a sense, the TVP-VAR shows that there was information available before the actual onset of the Great Recession that put increased likelihood on very low interest rates at a five-year mark. Finally, the results for longer time horizons also show higher ZLB probabilities in the mid-1970s, the early 1980s, and the early 2000s. All three periods are characterized by large interest rate movements and higher macroeconomic volatility around and during recessions. This translates into more forecast uncertainty, which is reflected in higher ZLB probabilities.

3. CONCLUSION

This article discusses an approach to how policymakers can think about the risk of having to face the zero lower bound on the nominal interest rates. It is based on a forecasting model for the US economy that is flexible enough to capture nonlinearities such as the ZLB. Our main finding is that the probability of being at the ZLB is small but not insignificant for the US economy over a ten-year time horizon. Depending on how one interprets the notion of being at the ZLB, either over the course of a time path (our conditional measure) or as a pure point-in-time forecast (our unconditional measure), this likelihood is close to

[9] DSGE models have struggled with this feature of the data, too. See, for instance, Kiley and Roberts (2017). Jones (2017) does better than most by incorporating forward guidance explicitly into the policy rule.

one-fifth in the longer run, albeit it is close to zero over a shorter time horizon. A robustness exercise shows that our methodology is reasonably successful in capturing the probability of being at the ZLB before and during the Great Recession.

Our findings can inform the discussion on the pace of interest rate increases since the probability of being at the ZLB is inversely related to its distance from the interest rate, other things being equal. Whether a more aggressive path of hikes has the potential to tip the economy into recession, thereby stimulating interest rate cuts and an increased risk of the ZLB, depends on the underlying structure of the economy and its monetary transmission mechanism. It goes much beyond the scope of this article to assess whether the employed TVP-VAR is a good descriptor of this mechanism. Nevertheless, our estimated ZLB probabilities are also a convenient way of summarizing forecasts by condensing a lot of information into a single statistic. Overall, we regard the ZLB probabilities discussed in this article as a useful tool for policymakers to assess the current stance of monetary policy in light of the estimated likelihood that the policy will be constrained by the ZLB.

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Figure 1 Estimated Probabilities of Being at the Zero Lower Bound for Three Sample Periods

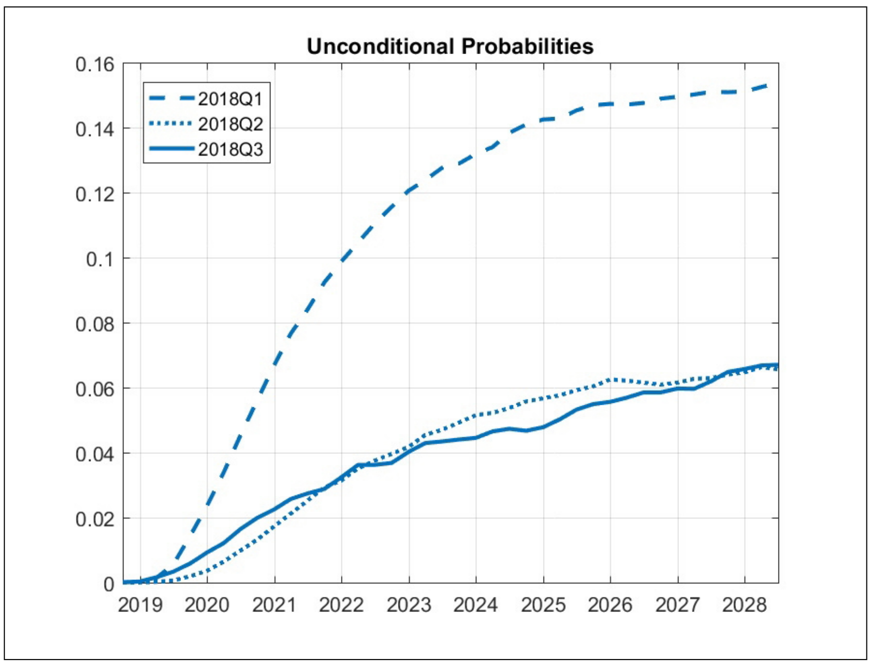

Figure 2 Estimated Probabilities of Being at the Zero Lower Bound for Three Sample Periods

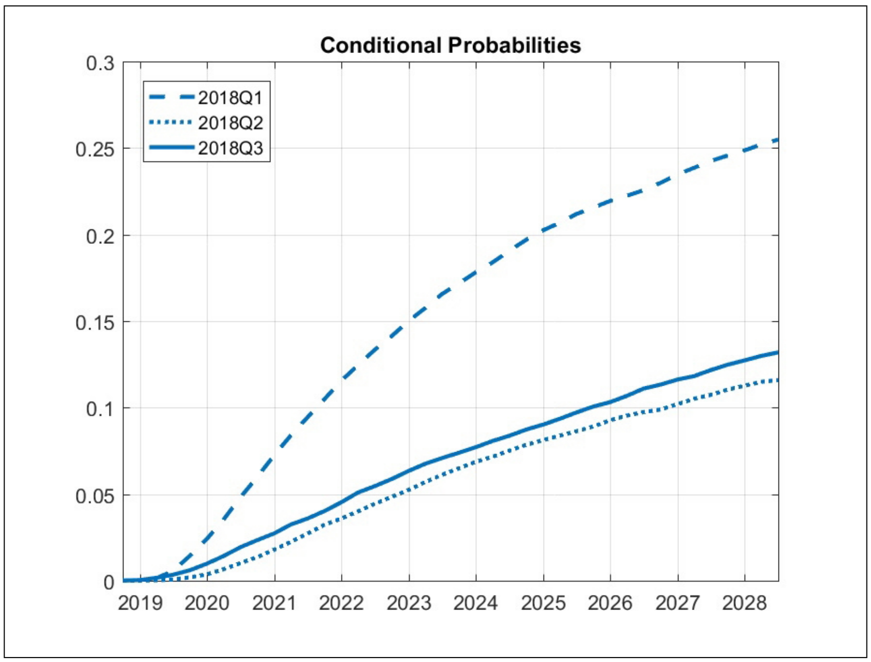

Figure 3 Probabilities of the Zero Lower Bound at Different Time Horizons